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INDEPENDENT REMEDIAL ACTION PLAN ADDENDUM Upland Areas

Prepared for: Barbee Mill Co., Inc.

Project No. 050004-001-07 • February 8, 2006 Draft





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Aspect Consulting, LLC

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Introduction

This report updates the Independent Remedial Action Plan (IRAP: Hart Crowser, September 6, 2000) for upland areas at the Barbee Mill facility in Renton, Washington. The IRAP was prepared for Barbee Mill Co., Inc. (Barbee Mill), and submitted to the Washington State Department of Ecology (Ecology) in Fall 2000. Barbee Mill is conducting cleanup of the site under Ecology's Voluntary Cleanup Program.

The IRAP outlined the following remedial actions to be conducted at the facility:

- Removing soils containing greater than 20 mg/kg arsenic to a depth of 15 feet and disposing off site at a permitted facility;
- Evaluating natural attenuation of arsenic in groundwater at the site, using groundwater monitoring data and fate-and-transport modeling;; and
- Implementing active groundwater remediation if necessary.

Aspect Consulting was retained by Barbee Mill to assist in implementation of the IRAP, including further evaluation of natural attenuation as the groundwater remedy. In August 2005, Aspect Consulting and S.S. Papadopoulos & Associates conducted a study of the potential effectiveness of natural attenuation following soil excavation. The study included collecting site geochemical data and use of the available data to model arsenic fate-and-transport after soil excavation. The study concluded that natural attenuation would not achieve arsenic cleanup levels in groundwater for more than 100 years. In subsequent discussions, Ecology indicated that this would not be considered an acceptable restoration time frame under the Model Toxics Control Act (MTCA).

Therefore a range of remedial alternatives that could address arsenic concentrations in groundwater were evaluated. These technologies would be used to remediate arsenic-impacted groundwater on the Barbee Mill property as well as that portion of the impacted groundwater that has migrated onto the adjoining Quendall Terminals property to the north. The primary pathway of concern for impacted groundwater from both of these areas is discharge to Lake Washington. A summary of the remedial technologies evaluated is provided in this IRAP addendum report. Based on this evaluation, the preferred alternative was identified and consists of the following elements:

- A permeable, subsurface passive attenuation zone along the shoreline. The attenuation zone would contain media to remove arsenic from groundwater.
- A pump-and-treat system upland from the passive attenuation zone. The pump-and-treat system would be operated in the short term to remove high concentrations of arsenic and improve the lifetime and effectiveness of the passive attenuation zone. When the pump and treat system's mass removal efficiency declines, it would be shut off.
- A deed restriction on the property to limit groundwater use and disturbance of the passive attenuation zone.

This IRAP Addendum includes:

- A summary of the natural attenuation study, including data collected since the 2000 IRAP;
- An evaluation of remedial alternatives for groundwater; and
- The conceptual design of the preferred remedial alternative.

Natural Attenuation Study

In August 2005, a soil and groundwater investigation was performed at the Barbee Mill site to better define the distribution of arsenic in site groundwater and to characterize key geochemical parameters that can affect arsenic fate and transport. Details of the investigation and a summary of collected data are provided in Appendix A. Key findings of the soil and groundwater investigation included:

- Arsenic concentrations detected at site monitoring wells in 2005 were consistent with concentrations detected in 1999 to 2000.
- The majority of arsenic in soil and groundwater is present in the reduced As(III) state, which is the more mobile of the two forms of inorganic arsenic.
- Site conditions appear to be naturally reducing, suggesting that groundwater redox conditions are likely to remain reducing after excavation of the arsenic source area.
- The mobility of arsenic at the Barbee Mill site is largely controlled by sorption onto clay minerals (e.g., smectite, illite, or kaolinite).
- The site-specific sorption coefficient of arsenic to soil (K_D) ranges between approximately 3 and 15 L/kg.

S.S. Papadopoulos & Associates simulated arsenic attenuation following source removal using VS2DI, a one-dimensional solute transport model. Details and results of the modeling are provided in Appendix B. Modeling results indicated the following:

- For a K_D of 3 L/kg, the estimated time for groundwater arsenic concentrations across the site to reach cleanup levels is greater than 100 years.
- As K_D increases, the estimated time to cleanup increases.

Remedial Alternatives for Groundwater

Remedial Action Objectives

Remedial action objectives for the site presented in the 2000 IRAP included protecting the direct contact pathway for soil under a residential use scenario and protecting surface water. These remedial action objectives are consistent with the proposed residential site use. Removing soils exceeding 20 mg/kg arsenic (presently being conducted) to a maximum depth of 15 feet will address the direct contact pathway for residential use. The specific objectives of the groundwater remedial action described in this report are as follows:

- Prevent exposure to arsenic via groundwater ingestion; and
- Prevent migration of arsenic in groundwater above site cleanup levels to Lake Washington.

The groundwater cleanup level for arsenic proposed in the 2000 IRAP was 0.008 mg/L, based on site background measurements at four groundwater monitoring wells. However, using procedures for defining background concentrations, as presented in the February 2001 revision of MTCA (WAC 173-340-709) and using MTCASat software for the statistical evaluation of existing data, the calculated site background concentration for arsenic in groundwater is 0.011 mg/L. The groundwater cleanup level of 0.011 mg/L is the groundwater cleanup level to be used to evaluate remedial action performance at the point of compliance.

Under MTCA, the standard point of compliance for groundwater is throughout the site. However under WAC 173-340-720(8), a conditional point of compliance may be set, with Ecology approval, in the event that remedial alternatives are not able to achieve the cleanup level at the standard point of compliance within a reasonable restoration time frame and where potential exposure pathways can be protected through the use of institutional controls. The evaluation of remedial alternatives indicates a long restoration timeframe associated with achieving cleanup levels in groundwater throughout the site. However it is feasible to address all exposure pathways through institutional controls consistent with future site use. Therefore a conditional point of compliance, located along the western extent of the Barbee Mill and Quendall Terminals properties along Lake Washington, is considered appropriate based on site conditions and is assumed for the purposes of evaluating remedial alternatives.

Remedial Technology Screening

Potential technologies that could be implemented as a groundwater remedy following soil excavation were screened on the basis of potential effectiveness, implementability, and cost. These technologies included:

- Excavation and off-site disposal of soil impacting groundwater;
- Excavation, *ex situ* stabilization, and replacement of soil impacting groundwater;

- *In situ* stabilization (using soil mixing and chemical additives) of soil impacting groundwater;
- *In situ* stabilization, using injection of chemical additives into groundwater;
- Installing a passive treatment 'attenuation zone' along the property boundary to prevent further off-site migration of impacted groundwater;
- Installing an impermeable containment barrier around impacted groundwater;
- Groundwater pump-and-treat;
- *In situ* soil flushing of saturated-zone soil (pump-and-treat that includes amending the extracted water and reinjecting into the affected area, with the purpose of mobilizing arsenic and enhancing removal);
- Arsenic removal from saturated-zone soil via electrokinetic remediation;
- Institutional controls; and
- Natural attenuation.

A summary of technology screening is provided in Table 1. Of the three soil stabilization technologies, *in situ* stabilization using soil mixing likely would be the most cost-effective method. The effectiveness of *in situ* stabilization using chemical injection would be limited by the presence of low-permeability and heterogeneous soils. *Ex situ* stabilization would require additional soil handling and dewatering for excavation and backfill. Soil stabilization technologies and excavation/off-site disposal may need to be applied over a very large area to meet remedial action objectives.

Electrokinetic remediation is a developing technology that has not been adequately demonstrated at the field level for arsenic-impacted soils. Sediment capping was not retained as a stand-alone technology because, if used by itself to treat the relatively high arsenic concentrations in groundwater, it could result in the hyper-accumulation of arsenic in a relatively thin layer of lake bed sediment.

The effectiveness of groundwater pump-and-treat (with or without soil flushing) is also limited by heterogeneous, low-permeability soils. Pump-and-treat and soil flushing were not retained as stand-alone technologies because of the projected long operating time and high cost of operating these systems to achieve cleanup objectives. However, because of the relatively high mobility of arsenic at the site, these technologies may be cost-effective as short-term measures to remove a portion of the residual arsenic mass and reduce the restoration time frame.

A passive attenuation zone (amending soil along the property boundary to enhance sorption of arsenic) would be effective at addressing arsenic exceedances in groundwater; however, addressing high arsenic concentrations in groundwater may require a very thick zone to provide adequate treatment and/or minimize accumulation of arsenic within the zone. This technology may be most effectively applied in conjunction with treating the higher arsenic concentrations in groundwater using another technology, such as pump and treat.

Surrounding impacted groundwater with an impermeable barrier could limit impacted groundwater from migrating to Lake Washington. However, success of this approach is dependent on keying into a continuous aquitard and limiting infiltration across the zone of impacted groundwater. Potential future use of the property would include lawns, greenspace, and other permeable surfaces. In addition, isolation of contaminated groundwater would limit natural attenuation and may require monitoring of the barrier in perpetuity.

Based on our evaluation of potential technologies, we have retained the following technologies for incorporation into remedial alternatives:

- *In situ* stabilization via soil mixing;
- *In situ* treatment via passive attenuation zone;
Pump-and-treat (with or without reinjection); and
- Soil excavation and off-site disposal.

In addition, natural attenuation is retained to supplement active remedial measures to the extent remedial action objectives can be achieved within a reasonable restoration time frame. Institutional controls are also retained to the extent that they are necessary to control exposure during the restoration time frame.

Description of Remedial Alternatives

Using the remedial technologies retained above, we have developed three potential remedial alternatives, as follows:

- Alternative 1 – Passive Attenuation Zone and Groundwater Pump-and-Treat
- Alternative 2 – In-Situ Stabilization
- Alternative 3 – Soil Excavation and Off-Site Disposal

The three proposed remedies involve technologies that are implemented upland of the shoreline; however, the available data suggest that impacted groundwater may extend beyond the shoreline beneath the lake. It is expected that all of the area beyond the shoreline immediately downgradient of the Barbee Mill site containing impacted groundwater will attenuate within a reasonable restoration timeframe (within 10 year period) with upland controls. However, higher arsenic concentrations in groundwater occur along the shoreline on the Quendall Terminals property. If impacted groundwater beyond the shoreline on the Quendall Terminals property does not attenuate within a reasonable restoration timeframe, a permeable reactive layer could be placed by amending sediments with an arsenic-attenuating material in the area where it is determined that attenuation of impacted groundwater discharge will not occur within a reasonable restoration timeframe. Amending sediments located in the off-shore area of the Quendall Terminals property with an arsenic-attenuating material has been retained as a contingency action for all three alternatives. This contingency action would need to consider other potential activities in this area associated with the environmental restoration activities on the Quendall Terminals property, such as woodwaste removal from the lake bed. Amending sediments could involve dredging to maintain the existing

shoreline bathymetry. Note that for cost comparison purposes, we have not included costs of potential contingency actions.

The three remedial alternatives are described below.

Alternative 1—Passive Attenuation Zone and Groundwater Pump and Treat

A passive attenuation zone would be installed along the shoreline to treat groundwater along the property boundary and/or shoreline. In addition, groundwater pump-and-treat would be implemented upgradient of the attenuation zone and in the interior of the site to address groundwater exhibiting the highest arsenic concentrations. The pump and treat system, although not effective as a stand alone technology, would accelerate the removal of mobile arsenic from groundwater and reduce the total mass of arsenic entering the attenuation zone. It would also provide an opportunity to capture a portion of the impacted groundwater that has migrated beyond the property boundary. The pump-and-treat system would be shut down as mass removal becomes asymptotic, with the passive attenuation zone providing long-term treatment.

The passive attenuation zone constructed along the shoreline would consist of a permeable material, such as a mixture of clean soil and iron filings that would remove arsenic from groundwater via sorption and/or precipitation. Selecting and designing an appropriate material composition would require laboratory and field testing. The attenuation zone would need to function until such time as natural attenuation processes at the site, in combination with short term groundwater extraction and treatment, have reduced arsenic concentrations to below the site-specific cleanup level upgradient of the attenuation zone. The width and composition of the attenuation zone would be designed to avoid maintenance or replacement of the media during its required operational lifetime.

This alternative would include placing a restrictive covenant on groundwater use and on disturbance of soils within the passive attenuation zone for the duration of the attenuation period. The attenuation zone would be constructed within the 35-foot wide native plant buffer area to be located between the shoreline and future development on the Barbee Mill property, and similarly located along the shoreline on the Quendall Terminals property, pending approval by the land owners. If it is not possible to implement the remedy on the Quendall Terminals property, the alignment of the treatment zone would be modified to extend along the northern Barbee Mill property boundary. This alternative would require Ecology approval of a conditional point of compliance for groundwater.

Extraction wells, piping, treatment equipment, and monitoring wells would be installed on future common space (e.g., streets, water quality tracts) as practicable to allow access and maintenance. Each well would be connected via underground piping to the treatment system. Treated water would either be infiltrated on site or discharged to the sanitary sewer. Utility hookups for sewer and electricity would be installed at the extraction and treatment system location. An easement for the wells, piping, and treatment system may need to be obtained.

The estimated cost of this alternative is approximately \$4.4 Million.

Alternative 2–In-Situ Stabilization

Elevated arsenic concentrations in groundwater will persist after source removal because of desorption of arsenic from soil within the area of impacted groundwater. Stabilization involves adding amendments that stabilize arsenic to soil, preventing further desorption of arsenic from soil to groundwater. With *in-situ* stabilization, these amendments are typically injected into the soil as slurry and mixed with a large-diameter auger. The estimated volume of saturated-zone soils that would be treated within the area of impacted groundwater (after source removal) is 98,000 cubic yards.

Potential amendments for arsenic stabilization include cement or a mixture of ferric chloride and sodium silicate, in which the ferric chloride promotes arsenic precipitation and sodium silicate encapsulates the precipitated arsenic to stabilize long-term under reducing conditions. Cement has been more widely used and can also add structural integrity to the soils; however, it also reduces permeability and, therefore, affects infiltration and groundwater flow. Groundwater data collected to date indicate that arsenic at the site is relatively mobile and would require high concentrations of ferric chloride/sodium silicate to stabilize. There is also little long-term performance data for the silicate stabilization technology. Selecting and designing an appropriate amendment would require laboratory and field testing.

This alternative could potentially meet groundwater cleanup levels across the upland portion of the site, but may require institutional controls for impacted groundwater beyond the shoreline and Ecology approval of a conditional point of compliance for groundwater.

The estimated cost of this alternative, using ferric chloride and sodium silicate to stabilize arsenic, is approximately \$6.2 Million.

Alternative 3–Soil Excavation

This alternative involves removing all soil within the area of arsenic-impacted groundwater and disposing of the soil at a permitted facility. The excavation would be backfilled with clean soil. Because of the proximity of the excavation to Lake Washington, sheetpiles would be installed around the excavation perimeter to limit groundwater inflow. Groundwater removed to facilitate excavation would either be treated to meet sanitary sewer discharge requirements or, in the event that dewatering flow rates exceed the sewer discharge capacity, treated to site cleanup levels and infiltrated on site. The estimated volume of saturated-zone soils that would be removed within the area of impacted groundwater (after source removal) is 98,000 cubic yards.

This alternative could potentially meet groundwater cleanup levels across the upland portion of the site, but may require institutional controls for impacted groundwater beyond the shoreline and Ecology approval of a conditional point of compliance for groundwater.

The estimated cost of this alternative is approximately \$13.4 Million.

Evaluation of Remedial Alternatives

All three of the remedial alternatives presented above would achieve remedial action objectives and meet the minimum requirements for cleanup actions under MTCA (WAC 173-340-360). All alternatives potentially require a conditional point of compliance and institutional controls to address impacted groundwater extending beyond the shoreline. Alternative 1 includes setting a conditional point of compliance for groundwater, placing restrictions on the upland portion of the site to prevent withdrawal of groundwater for drinking and to prevent disturbance of the attenuation zone and long-term upland groundwater monitoring. These restrictions and activities are compatible with the proposed site use. Alternatives 2 and 3 may potentially achieve cleanup levels over a larger area but the costs of these alternatives are substantial and disproportionate to the benefits. The iron and silicate stabilization technology of Alternative 2 is relatively unproven at field scale. Alternatives 2 and 3 would also have a greater short-term environmental impact because extensive construction activities and truck traffic would be required. Therefore, Alternative 1 – Passive Attenuation Zone and Pump-and-Treat is the preferred remedial alternative.

Conceptual Remedial Design

A conceptual plan-view layout of the preferred remedial alternative is provided in Figure 1, and a cross-section schematic is provided in Figure 2. The proposed remedial alternative consists of three general activities: Construction of a pump-and-treat system in the upland portion of the site, construction of a passive attenuation zone along the shoreline, and compliance monitoring. The proposed alternative also includes setting a conditional point of compliance for groundwater and placing a deed restriction on the property. Conceptual design elements for each remedial activity are outlined below.

Pump-and-Treat System

The purpose of the pump-and-treat system is to reduce the load on the attenuation zone and allow the attenuation zone to operate without maintenance or replacement of the media. Design considerations for the pump-and-treat system include:

- **Well Spacing and Extraction Rate.** Preliminary groundwater modeling based on available data indicate that approximately 10 wells, at a spacing of 60 feet, and a total extraction rate of 15 gpm, may be sufficient to capture highly elevated concentrations of arsenic remaining in groundwater. Design details will be refined in design studies.
- **Groundwater Treatment.** Active treatment may be necessary to remove arsenic (e.g., via filtration, precipitation, or sorption). Treated water could either be discharged to the sanitary sewer under a King County discharge permit, or if effluent concentrations are below site cleanup levels, infiltrated in the uplands of the site.

- **System Location.** Groundwater extraction wells or trenches and the treatment system would be installed in future common space areas, to allow access and maintenance;
- **System Operating Criteria.** The pump-and-treat system would be operated until arsenic groundwater concentrations have been reduced sufficiently for the attenuation zone to function without assistance or future maintenance. System infrastructure would be maintained after operation ceases so it could be easily restarted if appropriate based on compliance and performance monitoring.

Passive Attenuation Zone

The purpose of the passive attenuation zone is to prevent arsenic in groundwater from discharging to Lake Washington above the site cleanup level. Design considerations include:

- **Attenuation Zone Location.** The attenuation zone would be installed within the proposed 35-foot-wide native plant buffer on the Barbee Mill property, and would either extend north along the shoreline of the Quendall Terminals property (the preferred alternative) or along the northern Barbee Mill property boundary. Based on the current estimated extent of elevated arsenic concentrations in site groundwater, the attenuation zone may be constructed along an approximately 750-foot long section of shoreline to a depth of approximately 15 feet below the seasonal high water table. Horizontal and vertical extents would be determined by groundwater sampling during detailed design studies.
- **Attenuation Zone Media and Composition.** The width and composition of the attenuation zone may vary with the local concentration of arsenic and the chosen media. The attenuation media will be selected based on testing under site groundwater conditions. Granular iron is the most commonly applied media for removing arsenic from groundwater. Other media that have been successfully field- and/or pilot-tested include basic oxygen furnace slag, greensand, and activated alumina.
- **Construction Methods.** Construction methods may include ex-situ or in-situ amendment methods, depending on the media selected and the soil characteristics. Ex-situ construction would likely consist of shoring the proposed area with temporary sheetpile, dewatering the trench, excavating and amending the soil with the chosen media, and backfilling/compacting the mixture. Potential in-situ methods, such as injection and in-situ mixing of media using a large-diameter auger, would reduce or eliminate dewatering but would need to be pilot tested to ensure proper mixing and placement of the material.
- **Construction Dewatering.** If dewatering is necessary, groundwater treatment may be necessary to remove arsenic (e.g., via filtration, precipitation, or sorption). Treated water could either be discharged to the sanitary sewer under a King County discharge permit, or if effluent concentrations are below site cleanup levels, infiltrated in the uplands of the site.

- **Measures to Prevent Disturbance.** In addition to placing a restrictive covenant on the Barbee Mill property and possibly the Quendall Terminals property, the top of the attenuation zone would be capped at the seasonally high water table with a layer of quarry spalls and geotextile fabric, followed by a 2-foot-thick layer of topsoil for native plantings, to create a physical barrier to disturbance and mark the location of the zone.

Compliance Monitoring

Performance and confirmation monitoring would be performed during remediation to ensure that the remedial measures perform as designed and that remedial action objectives are achieved. A conceptual monitoring program would include the following:

- **Pump-and-Treat Performance Monitoring.** During pump-and-treat operation, extraction flow rates, local groundwater elevations, and treatment system influent and effluent arsenic concentrations would be regularly monitored to evaluate performance.
- **Confirmation Groundwater Monitoring.** Long-term monitoring would be conducted at permanent monitoring wells located within the attenuation zone footprint, with most wells located in the area of the highest arsenic concentrations. Monitoring would be conducted quarterly for the first two years and less frequently thereafter (at a minimum of annually), with the long-term frequency based on the consistency of data. Potential permanent monitoring well locations are shown on Figure 2. These wells would be used to evaluate compliance with remedial action objectives. Monitoring would also be conducted at well point WP-1B, located off-shore of Quendall Terminals in the center of the arsenic plume, 5 years after implementation of the upland remedies to evaluate the restoration time frame of arsenic-impacted groundwater beyond the shoreline, based on sediment pore water.
- **Upland Groundwater Monitoring.** After pump-and-treat operation ceases, long-term monitoring would also be conducted upland of the attenuation zone at former extraction wells to evaluate the attenuation of arsenic within the interior of the site.

Contingency Actions

The preferred remedy includes long-term compliance monitoring. Because the Barbee Mill property will likely be developed within the operating lifetime of the attenuation zone, potential contingency actions (in the event that compliance monitoring indicates additional action is required) need to be consistent with development. Potential contingency actions include:

- **Long-term Pump and Treat.** Pump-and-treat infrastructure (wells, piping, and treatment equipment) will be maintained when not operational in the event the system needs to be restarted in the future.
- **Sediment Attenuation Amendments.** If impacted groundwater beyond the shoreline on the Quendall Terminals property does not attenuate within a

reasonable restoration timeframe, a permeable attenuation layer consisting of amending existing sediments with an arsenic-attenuating material would be placed. Note that this contingency action would need to consider other potential activities in this area associated with the environmental restoration activities on the Quendall Terminals property, such as woodwaste removal from the lake bed.

Schedule

The anticipated schedule for design and implementation of the groundwater remedial action is as follows:

- **February 2006.** Submit the IRAP Addendum with the proposed groundwater remedial action to Ecology.
- **March 2006.** Meet with City of Renton to initiate the permitting process (conditioned on Ecology concurrence with the IRAP Addendum).
- **April 2006.** Submit application for environmental review and permits to the City of Renton.
- **April 2006 to August 2006.** Design remedial alternative, including bench and pilot studies.
- **September 2006.** Select the remediation contractor(s).
- **October to November 2006.** Construct attenuation zone and groundwater extraction/treatment system (conditional on receiving required permits).

Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Barbee Mill Co., Inc., for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Technology Screening Summary

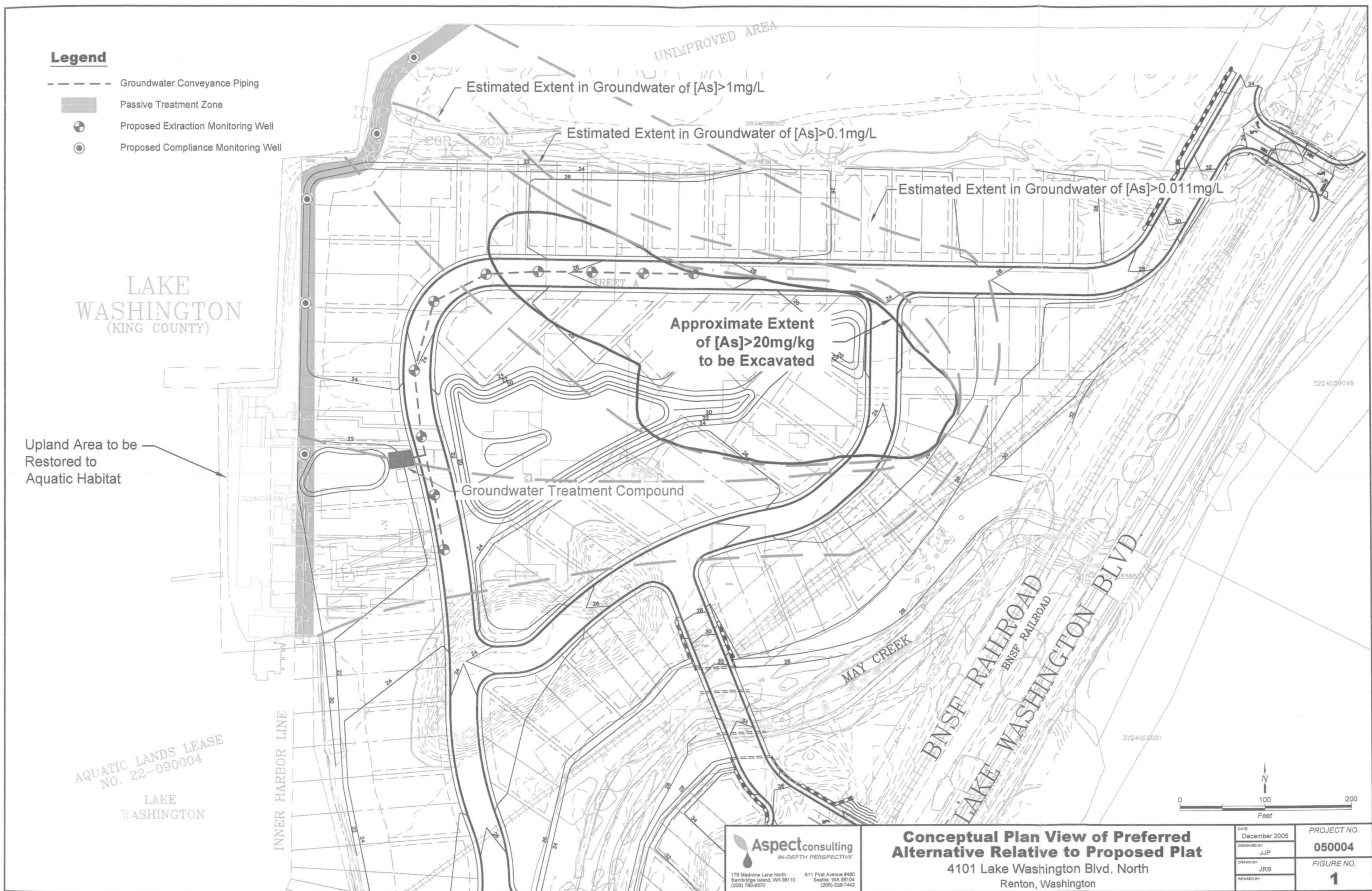
General Response Action	Potentially Applicable Remedial Technology	Effectiveness	Implementability	Cost	Screening Result
Institutional Controls	Deed restrictions	Medium	High	Low	Retained (See Note 1)
Natural Attenuation	Monitored natural attenuation	Low/Medium	High	Low	Retained (See Note 1)
Containment	Vertical barriers	Low	High	Medium	Not Retained
	Groundwater extraction	Medium	High	High	Not Retained
In Situ Treatment	In-situ stabilization via soil mixing	High	Medium	Medium/High	Retained.
	In-situ stabilization via chemical injection	Low/Medium	High	Medium	Not Retained
	Passive treatment attenuation zone	High	Medium	Medium	Retained
	Sediment amendments	Low/Medium	Medium	Medium	Retained (See Note 1)
Ex-Situ Treatment	Groundwater extraction and treatment/disposal	Low/Medium	High	Medium	Retained (See Note 1)
	Groundwater extraction and treatment/reinjection	Medium	Medium/High	Medium	Retained (See Note 1)
	Ex-situ soil stabilization	High	Low	High	Not Retained
	Soil excavation and off-site disposal	High	Low	High	Retained

Notes:

1) This technology is unlikely to be sufficiently effective by itself, but is retained because it can be applied cost-effectively in conjunction with other retained technologies.

Legend

- Groundwater Conveyance Piping
- Passive Treatment Zone
- ⊕ Proposed Extraction Monitoring Well
- ⊙ Proposed Compliance Monitoring Well



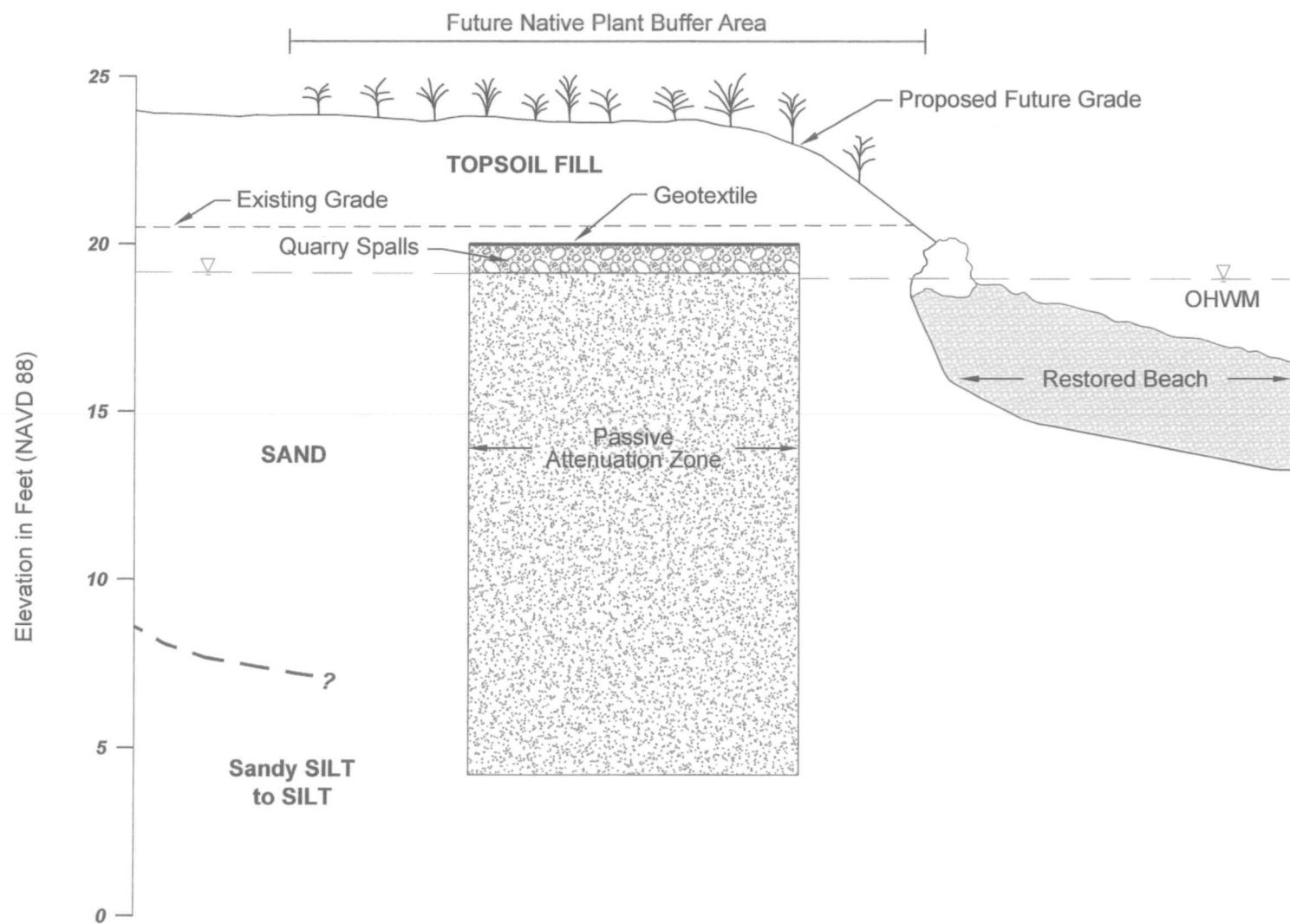
Aspect consulting
IN-DEPTH PERSPECTIVE

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(206) 780-9370

811 First Avenue #480
Seattle, WA 98104
(206) 328-7443

Conceptual Plan View of Preferred Alternative Relative to Proposed Plat
4101 Lake Washington Blvd. North
Renton, Washington

DATE	December 2005	PROJECT NO.	050004
DESIGNED BY	JJP	FIGURE NO.	1
DRAWN BY	JRS		
REVIEWED BY			



179 Madrone Lane North
Bainbridge Island, WA 98110
(206) 780-9370

811 First Avenue #480
Seattle, WA 98104
(206)-328-7443

Conceptual Cross Section of Passive Attenuation Zone

4101 Lake Washington Blvd. North
Renton, Washington

DATE:
November 2005
DESIGNED BY:
JJP
DRAWN BY:
JRS
REVISED BY:

PROJECT NO.
050004
FIGURE NO.
2

A



APPENDIX A

Summary of Site Geochemical Data (Aspect Consulting, 2005)

MEMORANDUM

Project No.: 050004-001-07

January 11, 2006

To: Robert Cugini, Barbee Mill Co., Inc.
cc: Lynn Manolopoulos, Davis Wright Tremaine
From: Jeremy Porter, P.E. and Tim Flynn, LHG
Re: **Summary of Site Geochemical Data**
Barbee Mill Property

This memorandum presents the results of our field investigation conducted at the Barbee Mill property in Renton, Washington, in August 2005. The purpose of this work was to collect site-specific data to be used in modeling arsenic fate-and-transport. S.S. Papadopoulos and Associates is performing modeling to predict arsenic behavior and estimate restoration time frames for a range of potential remedial alternatives.

Specific objectives of the field investigation included:

- Measure the current distribution of arsenic in site groundwater;
- Determine background and on-site redox conditions in shallow groundwater;
- Estimate a site-specific sorption coefficient (K_d) for arsenic with soil;
- Determine the primary mechanism(s) of arsenic attenuation at the site; and
- Measure geochemical parameters that affect arsenic mobility and/or treatment.

Field Explorations

Soil Samples

On August 3, 2005, Aspect Consulting collected soil samples from the Barbee Mill site using a direct-push probe rig supplied by Holt Drilling of Puyallup, Washington. Four soil borings (AP-1 through AP-4) were advanced next to existing monitoring wells as shown on Figure 1. Soil samples were collected at continuous 4-foot intervals using a dual tube sampler with disposable acrylic liner. Soil cores at the depth interval of the adjacent monitoring well screen were capped in the sample liner and stored in a cooler on ice and under argon gas. A sample core was also collected from the organic silt layer identified just below the shallow monitoring well screen interval at two locations. The correspondence between monitoring wells and soil probe samples is indicated on Table 1.

Soil cores were shipped to Columbia Analytical Services of Kelso, Washington, where they were frozen upon receipt. Cores from each interval were thawed and homogenized under nitrogen in a glove box. Homogenized samples were analyzed for the following:

- Total Metals (iron, manganese, and aluminum) by EPA Method 6010B;

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- Total Arsenic by EPA Method 6020;
- Total Organic Carbon by EPA Method 9060 Modified;
- Acid Volatile Sulfide by Draft 1991 Method; and
- Chromium Reducible Sulfur by Fossing & Jorgensen Method.

A split sample from each of samples AP-1 5-8, AP-2 53-8, AP-3 5-8 and AP-3 10.5-12 was shipped to S.S. Papadopoulos & Associates in Portland, Oregon to be analyzed for the following:

- Mineralogy analysis by scanning electron microscopy and x-ray diffraction.
- Sequential extraction to characterize arsenic fractions.

Groundwater Samples

On August 2, 2005, Aspect Consulting collected groundwater samples from eight wells, as shown on Figure 1: HCMW-01D, HCMW-01S, HCMW-02, HCMW-03, HCMW-05D, HCMW-05S, RMW-01, and RMW-03. Wells were purged and samples were collected using low-flow techniques. Parameters measured in the field included temperature, conductivity, pH, dissolved oxygen, and redox potential. Samples were submitted to Columbia Analytical Services for analysis for the following:

- Sulfate, Nitrate, Nitrite, and Chloride by EPA Method 300.0;
- Arsenic Speciation by Method 1632 (Subcontracted to Brooks-Rand of Seattle, Washington);
- Alkalinity by EPA Method 310.1;
- Ortho Phosphorus by EPA Method 365.3;
- Sulfide by EPA Method 376.2;
- Biochemical Oxygen Demand (BOD) by EPA Method 405.1;
- Total Organic Carbon (TOC) by EPA Method 415.1;
- Dissolved Metals (calcium, iron, magnesium, manganese, potassium, silicon, and sodium) by EPA Method 6010B; and
- Dissolved Arsenic by EPA Method 6020.

Well Point and Sediment Pore Water Samples

On August 10, 2005, Aspect Consulting installed two well points (WP-1B and WP-5) off shore at locations shown on Figure 1. Each well point was installed to a depth of 4 feet, with a screen from a depth of 2 to 4 feet below mudline. Well points were purged and sampled using low-flow techniques. Parameters measured in the field included temperature, conductivity, pH, dissolved oxygen, and Eh. Samples were submitted to Columbia Analytical Services. The sample from WP-1B was submitted for analysis for the following:

- Sulfate, Nitrate, Nitrite, and Chloride by EPA Method 300.0;
- Alkalinity by EPA Method 310.1;
- Ortho Phosphorus by EPA Method 365.3;
- Sulfide by EPA Method 376.2;
- Biochemical Oxygen Demand (BOD) by EPA Method 405.1;
- Total Organic Carbon (TOC) by EPA Method 415.1;

MEMORANDUM

Project No.: 050004-001-07

January 11, 2006

- Dissolved Metals (calcium, iron, magnesium, manganese, potassium, silicon, and sodium) by EPA Method 6010B; and
- Dissolved Arsenic by EPA Method 6020.

The sample from WP-5 was submitted for analysis for arsenic only.

Sediment pore water samples were collected at each well point location using nylon screen samplers. DI water was sparged with nitrogen until the dissolved oxygen concentration was less than 1 mg/L. The deoxygenated water was placed in 10-ml polyethylene bottles with perforated caps fitted with 50-micron nylon screens. Sample bottles were placed in sediment next to the well point at a depth of 10 cm. Bottles were collected at one-week intervals and submitted to Advanced Analytical of Bellevue, Washington for analysis of dissolved arsenic (filtered by the laboratory).

Results

Chemical sampling results are summarized in Tables 1 and 4 for soil samples, Table 2 for groundwater and well point samples, and Table 3 for sediment pore water samples. Laboratory certificates of analysis are provided in Attachment A.

Mineralogic analysis of samples indicated that site soils primarily contain quartz, feldspar, clay minerals (smectite, illite, kaolinite), chlorite, and amphibole. Organic silt samples also contain abundant diatoms, with cell walls made of silica (opal-CT). Notably, iron oxides, either as discrete grains or coatings, were absent, indicating that the mobility of arsenic in groundwater at the site is most likely controlled by sorption on clay minerals.

Collocated soil and groundwater data indicate that arsenic sorption to soil is non-linear with varying arsenic concentrations. Calculated K_d (sorption coefficient) values for three collocated soil-groundwater samples are between 3 and 15 L/kg, and inversely correlated with groundwater concentration. This is consistent with the range of K_d values for arsenic(III) reported in the literature (approximately 3 to 30 L/kg).

Attachments:

Table 1 – Summary of Analytical Results for Soil Samples

Table 2 – Summary of Analytical Results for Groundwater Samples

Table 3 – Summary of Analytical Results for Porewater Samples

Table 4 – Sequential Extraction Results for Arsenic

Figure 1 – Exploration Locations

Attachment A – Laboratory Certificates of Analysis (Included on CD)

Columbia Analytical Services, Inc.

Brooks-Rand, Inc.

Advanced Analytical, Inc.

Table 1 - Summary of Analytical Results for Soil Samples

Sample	Depth Interval in Feet	Collocated Monitoring Well	Material Type	Concentration in Percent		Concentration in mg/kg					
				Total Solids in Percent	Total Organic Carbon	Sulfur - Chromium Reducible	Sulfide - Acid Volatile	Aluminum	Arsenic	Iron	Manganese
AP-1 3-8	3 to 8	HCMW-01S	medium-to-fine Sand	84.6	3.9	15.3	0.5 U	9,290	12	14,100	203
AP-1 15-20	15 to 20	HCMW-01D	medium-to-fine Sand	80.8	0.26	1.9	0.5 U	7,920	2.43	11,500	169
AP-2 3-8	3 to 8	RMW-01	silty Sand	78.1	0.94	19.7	0.5 U	14,600	2.99	18,200	257
AP-3 3-8	3 to 8	HCMW-02	gravelly Sand	79.1	1.33	4.4	0.5 U	10,700	73.2	17,400	225
AP-3 10.5-12	10.5 to 12	Interval below HCMW-02	organic Silt	50.3	4.82	80	0.5 U	11,400	13.5	12,800	283
AP-4 8-13	8 to 13	HCMW-05S	medium Sand with organic silt	78.8	0.15	6.6	0.5 U	9,490	0.92	12,100	142
AP-4 16.5-18	16.5 to 18	Interval between HCMW-05S and -05D	organic Silt	48.9	7.09	62.6	1.4	22,500	9.07	23,900	411
AP-4 20-24	20 to 24	HCMW-05D	fine-to-medium Sand	87.2	0.02 U	8.8	0.5 U	12,300	1.27	21,500	267

Table 2 - Summary of Analytical Results for Groundwater Samples

Field Parameters

Well	Date	pH	Temp in Celsius	Conductivity In uS	Dissolved Oxygen in mg/L	Eh In mV
HCMW-1D	8/2/2005	7.25	13.79	571	0.8	-46.4
HCMW-1S	8/2/2005	6.9	19.18	523	0.73	-54.1
HCMW-2	8/2/2005	6.74	18.59	412	0.72	17.2
HCMW-3	8/2/2005	6.78	22.02	324	0.68	13.6
HCMW-5S	8/2/2005	6.59	15.04	261	0.98	-2.7
HCMW-5D	8/2/2005	7.09	13.61	307	0.87	-79.4
RMW-01	8/2/2005	7.16	20.65	1731	0.5	-111.8
RMW-04	8/2/2005	6.72	23.56	166	0.43	31.1
WP-1B	8/10/2005	6.67	21.18	606	0.86	-71.4
WP-5	8/10/2005	6.92	20.66	323	1.1	-30.4
Lake Washington ⁽¹⁾	8/10/2005	7.39	23.18	105	9.09	17.4

Conventional Parameters

Well	Date	Concentration in mg/L							
		Total Alkalinity ⁽²⁾	BOD	Chloride	Sulfate	Nitrite ⁽³⁾	Nitrate ⁽²⁾	Ortho-phosphate ⁽⁴⁾	Total Sulfide TOC
HCMW-1D	8/2/2005	300	4 U	4.9	4.1	0.01 U	0.008 J	0.45	0.04 J 3.4
HCMW-1S	8/2/2005	215	6	3.1	0.2 U	0.01 U	0.09	0.007 J	0.04 J 14.3
HCMW-2	8/2/2005	155	6	2.8	0.2 U	0.01 U	0.06	0.1	0.007 J 19.4
HCMW-3	8/2/2005	118	1.8 J	2.9	0.2 U	0.01	0.08	0.5	0.03 J 10
HCMW-5D	8/2/2005	100	4 U	4.3	0.2 U	0.01 U	0.03 J	0.009 J	0.005 J 4.3
HCMW-5S	8/2/2005	138	4 U	1.3	5.4	0.01 U	0.7	0.006 J	0.007 J 4.1
RMW-01	8/2/2005	865	7	14	0.2 U	0.01 U	0.12	0.01	0.05 U 65.9
RMW-04	8/2/2005	57	2.8 J	2.3	0.2 U	0.007 J	0.04 J	0.95	0.03 J 11.1
WP-1B	8/10/2005	240	13	3.8	0.2 U	0.005 J	0.08	0.06	0.04 J 23.1

Metals

Well	Date	Concentration in mg/L												
		Dissolved Arsenic Speciation					Dissolved Metals by EPA Method 6010B							
		Inorganic Arsenic	Arsenic(III)	Arsenic(V) ⁽⁵⁾	Arsenic (MMA)	Arsenic (DMA)	Total Arsenic ⁽⁶⁾	Calcium	Iron	Magnesium	Manganese	Potassium	Silicon	Sodium
HCMW-1D	8/2/2005	0.0159	0.0131	0.0028	0.000008 U	0.000053 U	0.0159	58.8	1.34	23	2.1	4.59	22.5	30.8
HCMW-1S	8/2/2005	3.45	2.743	0.707	0.001 U	0.008 U	3.85	43.6	41.4	15.5	4.71	5.71	28.7	12.8
HCMW-2	8/2/2005	37.035	35.1	1.935	0.01 U	0.08 U	32.5	36.2	25.7	14	1.61	3.92	26.4	11.7
HCMW-3	8/2/2005	0.270	0.221	0.049	0.00008 U	0.00053 U	0.258	23.1	26.5	8.41	1.21	4.12	20	9.37
HCMW-5D	8/2/2005	0.0098	0.00633	0.00347	0.000006 U	0.00004 U	0.0087	27.8	9.03	11.2	1.07	4.64	20.8	10.9
HCMW-5S	8/2/2005	0.0090	0.00504	0.00396	0.000008 U	0.00004 U	0.0087	24.4	16	7.28	1.26	1 U	17.1	7.36
RMW-01	8/2/2005	0.096	0.06	0.036	0.00002 U	0.00016 U	0.0955	155	98.7	84.8	9.78	3.76	29.8	48.9
RMW-04	8/2/2005	0.015	0.0046	0.0102	0.000018 J	0.00004 U	0.009	11.3	10.4	3.25	0.841	2.94	15.8	5.14
WP-1B	8/10/2005	--	--	--	--	--	2.49	55.2	53.3	16.2	4.26	5.91	28.6	15.1
WP-5	8/10/2005	--	--	--	--	--	0.038	--	--	--	--	--	--	--

⁽¹⁾ measured 1 foot beneath surface next to WP-1B⁽²⁾ as calcium carbonate⁽³⁾ as nitrogen⁽⁴⁾ as phosphorus⁽⁵⁾ calculated by subtracting Arsenic(III) from Inorganic Arsenic⁽⁶⁾ by EPA Method 6020

TOC Total Organic Carbon

BOD Biochemical Oxygen Demand

U not detected at indicated reporting limit

J estimated value

Table 3 - Summary of Analytical Results for Porewater Samples

Location	Sample Name	Sample Depth in cm ⁽¹⁾	Date		Time Deployed in Hours	Dissolved Arsenic Concentration in mg/L ⁽²⁾
			Sampler Deployed	Sampler Collected		
WP-1B	PW-WP1B-1	10	8/10/05	8/16/05	144	0.005 U
	WP1B - PW2	10	8/10/05	8/25/05	359	4.5
	WP1B - PW3	10	8/10/05	9/1/05	529	0.011
	WP1B - PW4	10	8/10/05	9/9/05	718	1.4
WP-5	PW-WP5-1	10	8/10/05	8/16/05	144	0.012
	WP5 - PW2	10	8/10/05	8/25/05	359	0.022
	WP5 - PW3	10	8/10/05	9/1/05	529	0.021

Notes:

⁽¹⁾ below mudline

⁽²⁾ filtered by the laboratory

U not detected at indicated detection limit

Table 4 - Sequential Extraction Results for Arsenic

Sample	Replicate	Arsenic Concentration (mg/kg)				
		Soluble	Exchangeable	Sulfide/Organic	Residual	Total
AP 1-3-8	1	0.90	9.33	0.33	--	--
	2	0.70	12.1	0.41	8.55	21.8
AP 3-3-8	1	5.65	51.4	4.25	1.90	63.2
	2	6.07	42.1	3.22	6.00	57.4
AP 3-10.5-12	1	0.40	11.0	0.45	0.64	12.5
	2	0.76	10.9	0.48	--	--

-- Not analyzed due to autosampler failure during run. Total not calculated.

Analysis performed by Dimitri Vlassopoulos (S.S. Papadopolus & Associates) and Ben Perkins (Portland State University)

Sequential extraction procedure designed to release arsenic fractions according to their availability, as follows:

Soluble fraction extracted with 1 M $MgCl_2$, pH 8





Exchangeable (strongly absorbed) fraction extracted with 1 M NaH_2PO_4 , pH 5

Sulfide/organic fraction extracted with 0.1 M NaOH

Residual fraction extracted with 16 N HNO_3 + 30% H_2O_2

Sequential extraction methods adapted from methods published by Wilkin and Ford (2002), Keon et.al. (2001), and Dhoun and Evans (1998)

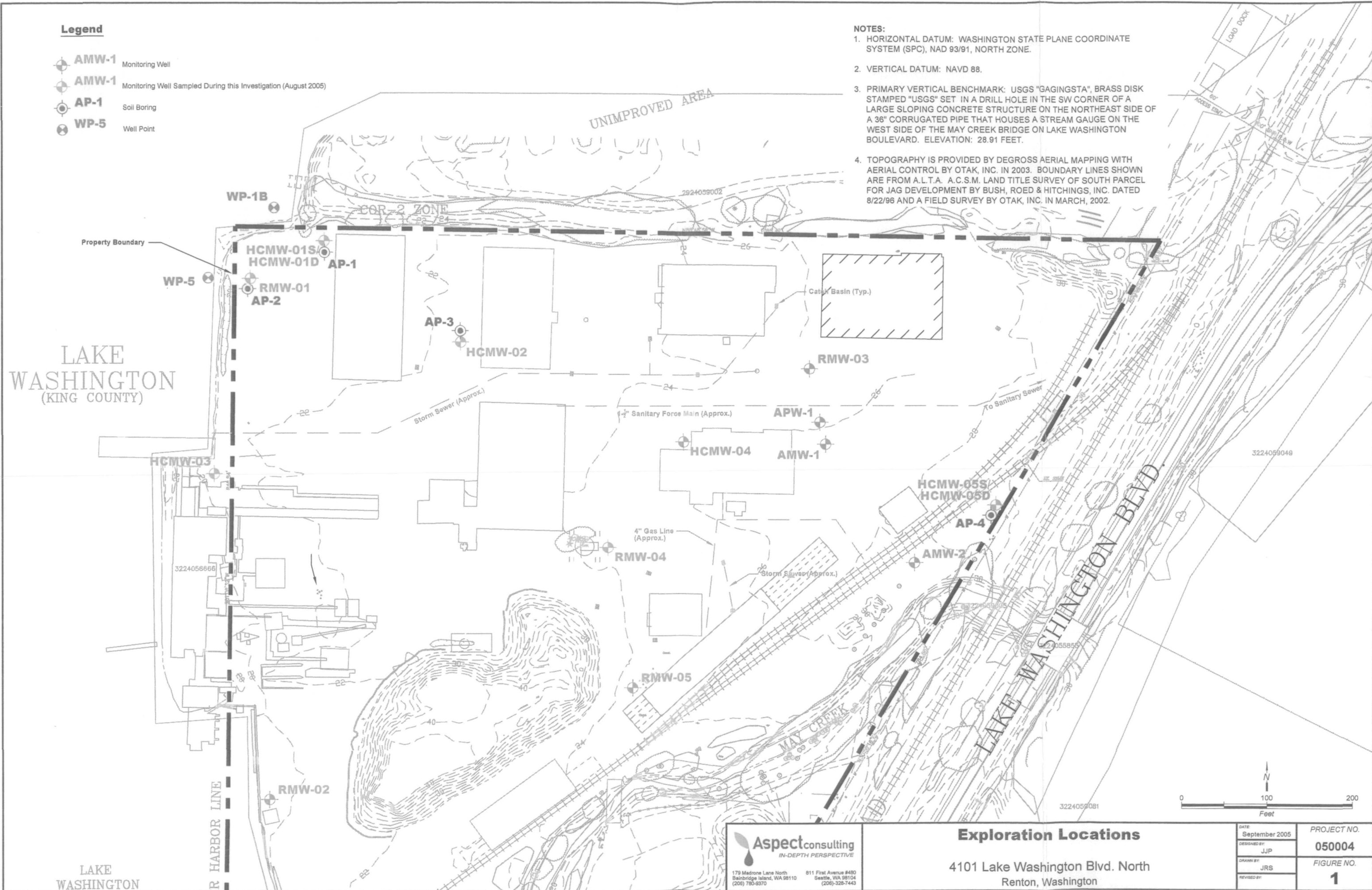
Legend

-  **AMW-1** Monitoring Well
-  **AMW-1** Monitoring Well Sampled During this Investigation (August 2005)
-  **AP-1** Soil Boring
-  **WP-5** Well Point

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE COORDINATE SYSTEM (SPC), NAD 93/91, NORTH ZONE.
2. VERTICAL DATUM: NAVD 88.
3. PRIMARY VERTICAL BENCHMARK: USGS "GAGINGSTA", BRASS DISK STAMPED "USGS" SET IN A DRILL HOLE IN THE SW CORNER OF A LARGE SLOPING CONCRETE STRUCTURE ON THE NORTHEAST SIDE OF A 36" CORRUGATED PIPE THAT HOUSES A STREAM GAUGE ON THE WEST SIDE OF THE MAY CREEK BRIDGE ON LAKE WASHINGTON BOULEVARD. ELEVATION: 28.91 FEET.
4. TOPOGRAPHY IS PROVIDED BY DEGROSS AERIAL MAPPING WITH AERIAL CONTROL BY OTAK, INC. IN 2003. BOUNDARY LINES SHOWN ARE FROM A.L.T.A. A.C.S.M. LAND TITLE SURVEY OF SOUTH PARCEL FOR JAG DEVELOPMENT BY BUSH, ROED & HITCHINGS, INC. DATED 8/22/96 AND A FIELD SURVEY BY OTAK, INC. IN MARCH, 2002.

LAKE
WASHINGTON
(KING COUNTY)



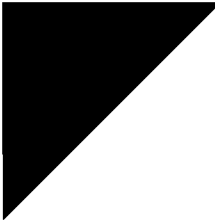
Aspect consulting
IN-DEPTH PERSPECTIVE
179 Madrone Lane North
Bainbridge Island, WA 98110
(206) 780-9370
811 First Avenue #480
Seattle, WA 98104
(206) 328-7443

Exploration Locations

4101 Lake Washington Blvd. North
Renton, Washington

DATE: September 2005	PROJECT NO. 050004
DESIGNED BY: JJP	FIGURE NO. 1
DRAWN BY: JRS	
REVISED BY:	

B



APPENDIX B

**Initial Cleanup Time Estimate for
Barbee Mill Upland Areas (S.S.
Papadopoulos & Associates, 2005)**

Memorandum

Date: October 19, 2005
From: Dimitri Vlassopoulos
To: Jeremy Porter (Aspect Consulting)
Project: SSP-0971 Barbee Mill
Subject: Initial Cleanup Time Estimate for Barbee Mill Upland Areas

This document provides an estimate for cleanup time by natural attenuation at the Barbee Mill Property in Renton, Washington. In arriving at this estimate, a conceptual model for arsenic transport at the site was developed based on a review of available soil and groundwater data. Given the limited amount of geochemical data available at the onset of the project, the conceptual model was implemented as a 1-D solute transport model which was used to make a preliminary evaluation of natural attenuation cleanup times for groundwater following source removal (excavation of soils with arsenic concentrations above 20 mg/kg) under various assumed scenarios. The model was also used to identify parameters to which the simulated cleanup times are most sensitive, and to assess uncertainty in the predicted cleanup times resulting from parameter uncertainty.

Conceptual Model

A review of available site data (summarized in Hart Crowser, 2000, with additional supporting information provided by Aspect) indicates that shallow groundwater is contaminated by arsenic to concentrations up to 52 mg/L. The arsenic plume defined by arsenic concentrations greater than 1 mg/L is approximately 200 feet wide and 700 feet long. The plume is elongated in a northwesterly direction parallel to groundwater flow originating in the vicinity of the former Spray Area and terminating at the shore of Lake Washington. The plume appears to have originated from past spills of solutions containing arsenic trioxide. Subsurface conditions across the site are reducing as indicated by low dissolved oxygen and redox potential (ORP), and elevated dissolved iron concentrations in groundwater. The arsenic in arsenic trioxide is present in the reduced arsenite or As(III) oxidation state. Arsenic speciation data also indicate dissolved arsenic in groundwater is also present predominantly as As(III). As(III) species are generally more soluble and mobile in water than the oxidized arsenate or As(V) species, which are more strongly retarded in groundwater by sorption reactions on the aquifer matrix.

The transport of dissolved arsenic under site groundwater conditions is influenced by the rate of groundwater flow and dispersion, sorption processes, redox reactions, and possibly precipitation-dissolution reactions. It is notable that conditions appear to be more or less uniformly reducing



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across the site, and that no significant redox gradients are present in the shallow aquifer under current conditions. Precipitation-dissolution reactions can also be ruled out as soil arsenic concentrations (0.78 to 830 mg/kg) are generally too low to indicate the presence of separate arsenic compounds. The main geochemical process affecting groundwater arsenic concentrations at the site is therefore sorption.

Groundwater Flow and Transport Modeling

A transport model for arsenic was developed implementing the natural attenuation processes identified in the conceptual model. A 1-D representation of flow and transport was considered adequate for screening level evaluations of cleanup time. The model simulations were carried out using VS2DI (Hsieh, P.A., W. Wingle, and R.W. Healy, 2000, VS2DI -- A graphical software package for simulating fluid flow and solute or energy transport in variably saturated porous media: U.S. Geological Survey Water-Resources Investigations Report 99-4130, 16 p.). Model input data derived from available site data (to the extent possible) as well as the scientific literature. The values used are summarized in Table 1.

Table 1. Parameter values used in VS2DI model

Parameter	Value	Units	Remarks
Domain Length	900	ft	
Groundwater Flow			
Hydraulic Conductivity	4500	ft/yr	Average of 11 values from Table 2 in Hart Crowser (2000)
Hydraulic Gradient	0.007	ft/ft	Estimated from Figures 6 and 7 in Hart Crowser (2000)
Transport			
Dispersivity	10	ft	
Porosity	0.25		
Bulk Density	1.7	kg/L	
Soil-Water Partition Coefficient	29	L/kg	Default MTCA value
	3	L/kg	Lower bound estimate

As implemented, the model can be used to estimate the cleanup time of the shallow aquifer by natural attenuation. An initial arsenic concentration distribution is assumed along the model domain and the model is run for sufficient simulation time to achieve cleanup levels everywhere within the model domain. To evaluate cleanup times under different assumed initial concentrations, arsenic concentrations at the most down-gradient model node were monitored



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over the simulation time, as this would be the last part of the aquifer to attain the cleanup level by natural flushing.

Initial simulations indicated that the cleanup time estimates were most sensitive to the value of the soil-water partition coefficient (K_D), because it was not well constrained by available data. The MTCA default K_D value for arsenic is 29 L/kg. The reducing conditions in the aquifer and occurrence of dissolved arsenic mainly as As(III) suggest that a lower value may be more appropriate for the Barbee Mill site. Preliminary evaluation of arsenic concentrations in collocated soil and groundwater samples collected in August 2005 indicate that a site-specific K_D value may be closer to 3 L/kg. The effect of K_D value on cleanup time is illustrated in Figure 1. For this simulation, an average groundwater concentration of 0.1 mg/L was assumed to remain following source excavation. Under this scenario, cleanup times for natural attenuation are greater than 100 years.

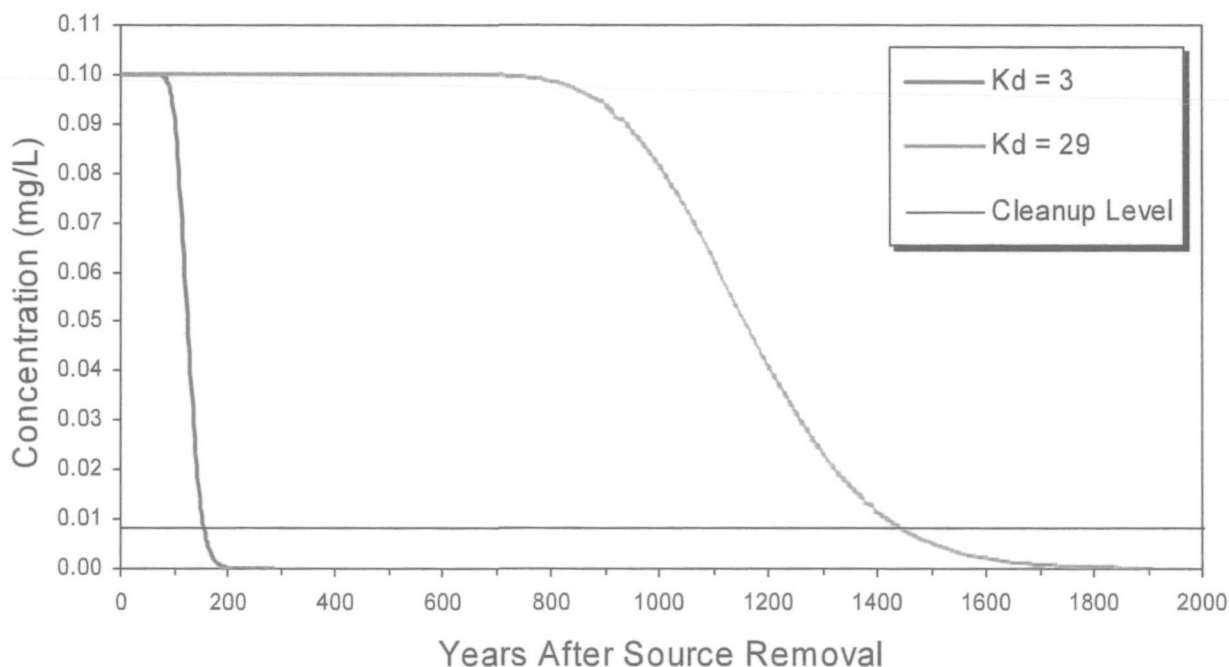


Figure 1. Effect of Soil-Water Partition Coefficient on Cleanup Time



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The model was also run for higher initial arsenic concentrations, to evaluate scenarios ranging from (1) limited source removal (1 mg/L) and (2) no source removal (20 mg/L). Predicted cleanup times for these scenarios were also greater than 100 years.

Conclusions

Model predicted cleanup times are sensitive to the K_D value assumed in the model. Available data indicates that the site-specific K_D is close to 3 L/kg. The predicted cleanup time to achieve a groundwater cleanup level of 0.008 mg/L by natural attenuation alone (i.e. without source area excavation) is greater than 100 years. Even after source removal actions are completed, modeling indicates that groundwater cleanup by natural attenuation would still take greater than 100 years.